

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE (DD-MM-YYYY)		2. REPORT TYPE Technical Papers		3. DATES COVERED (From r To)	
4. TITLE AND SUBTITLE				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER 3005	
				5e. TASK NUMBER 0062	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC) AFRL/PRS 5 Pollux Drive Edwards AFB CA 93524-7048				8. PERFORMING ORGANIZATION REPORT -----	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC) AFRL/PRS 5 Pollux Drive Edwards AFB CA 93524-7048				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT A	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Leilani Richardson
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (include area code) (661) 275-5015

680 6111

1 item enclosed

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MEMORANDUM FOR PR (In-House Publication)

FROM: PROI (TI) (STINFO)

06 December 1999

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-1999-0242**
McFall, K., "Solar Technology" (BFI)

JANNAF Propulsion Meeting (Tucson, AZ, 14-16 Dec 1999)

(Statement A)



**49th JANNAF Propulsion Meeting
Government Briefings for Industry**

**Solar Technology
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Outline



- Technology Description
- Propulsion Goals and Payoffs
- Funding Summaries
- Principal Technology Programs and Major Tasks
- Major Tasks and Accomplishments
- Major Tasks: FY00 and FY01
- Summary & Conclusion

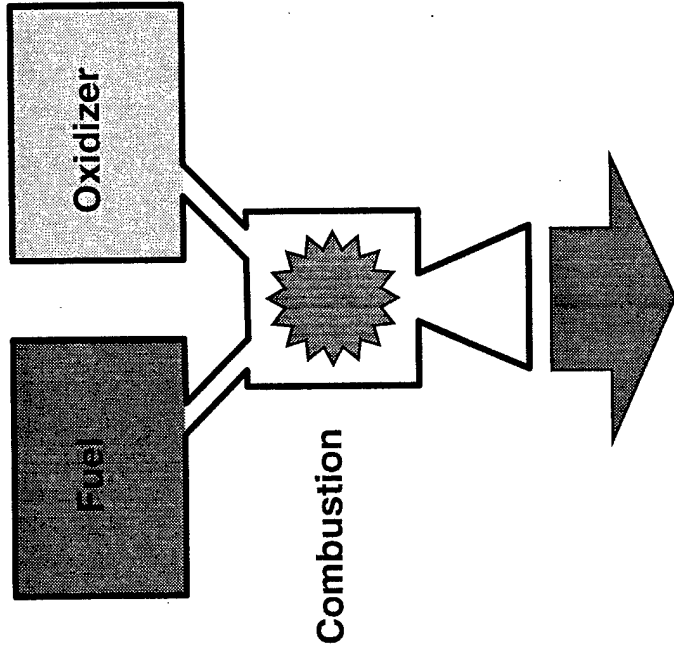


Solar Thermal Propulsion Technology Concept



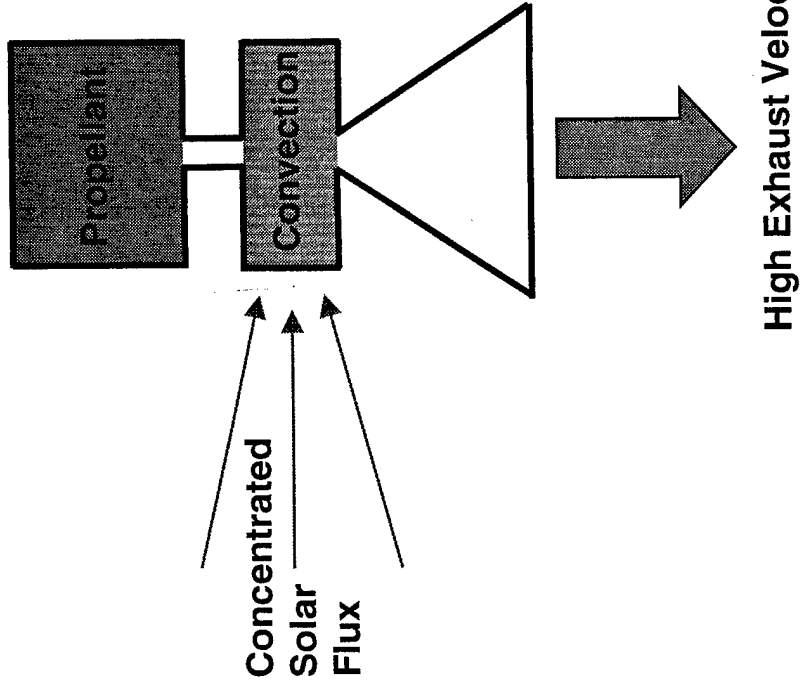
Chemical Rocket

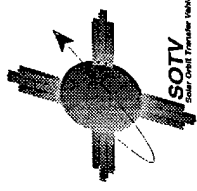
- High Thrust, Low Trip Time
- High Propellant Mass Flow Rate
- High Molecular Weight Propellant



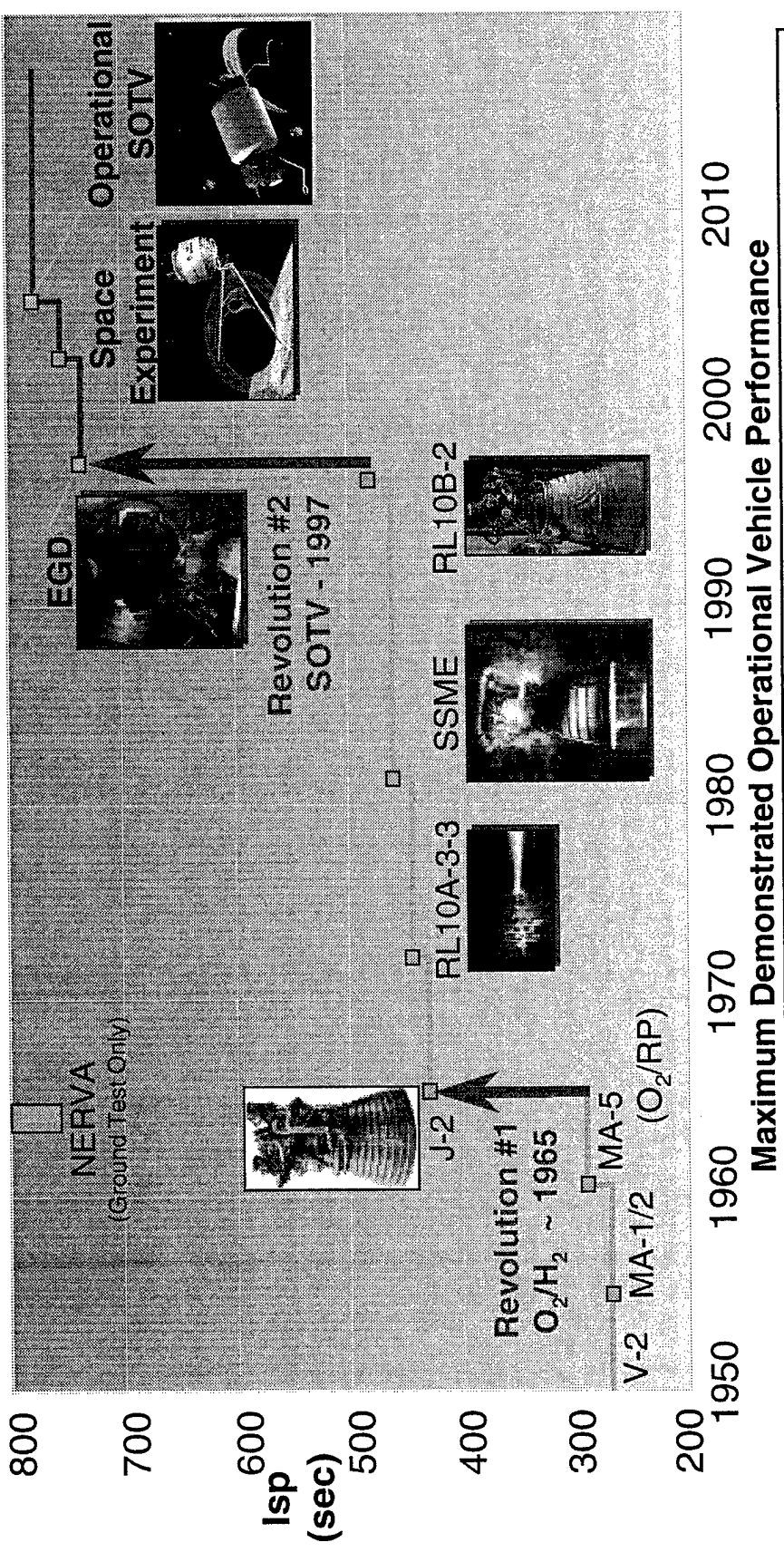
Solar Thermal Rocket

- Low Thrust, High Trip Time
- Low Propellant Mass Flow Rate
- Low Molecular Weight Propellant





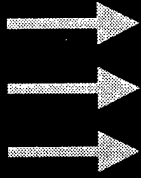
Solar Propulsion Projected System Trends



The next ten years of SOTV development could double the progress made in the last forty years of chemical rocket development

Solar Thermal System Concept

Sunlight



Concentrator:
Intersection
of paraboloid and
Cone with Apex at
Focal Point; Torus
is Elliptical and
Lies in Plane

Thin Film
Paraboloid
Concentrator

Pivot Axis of
Concentrators

Thruster
Nozzle

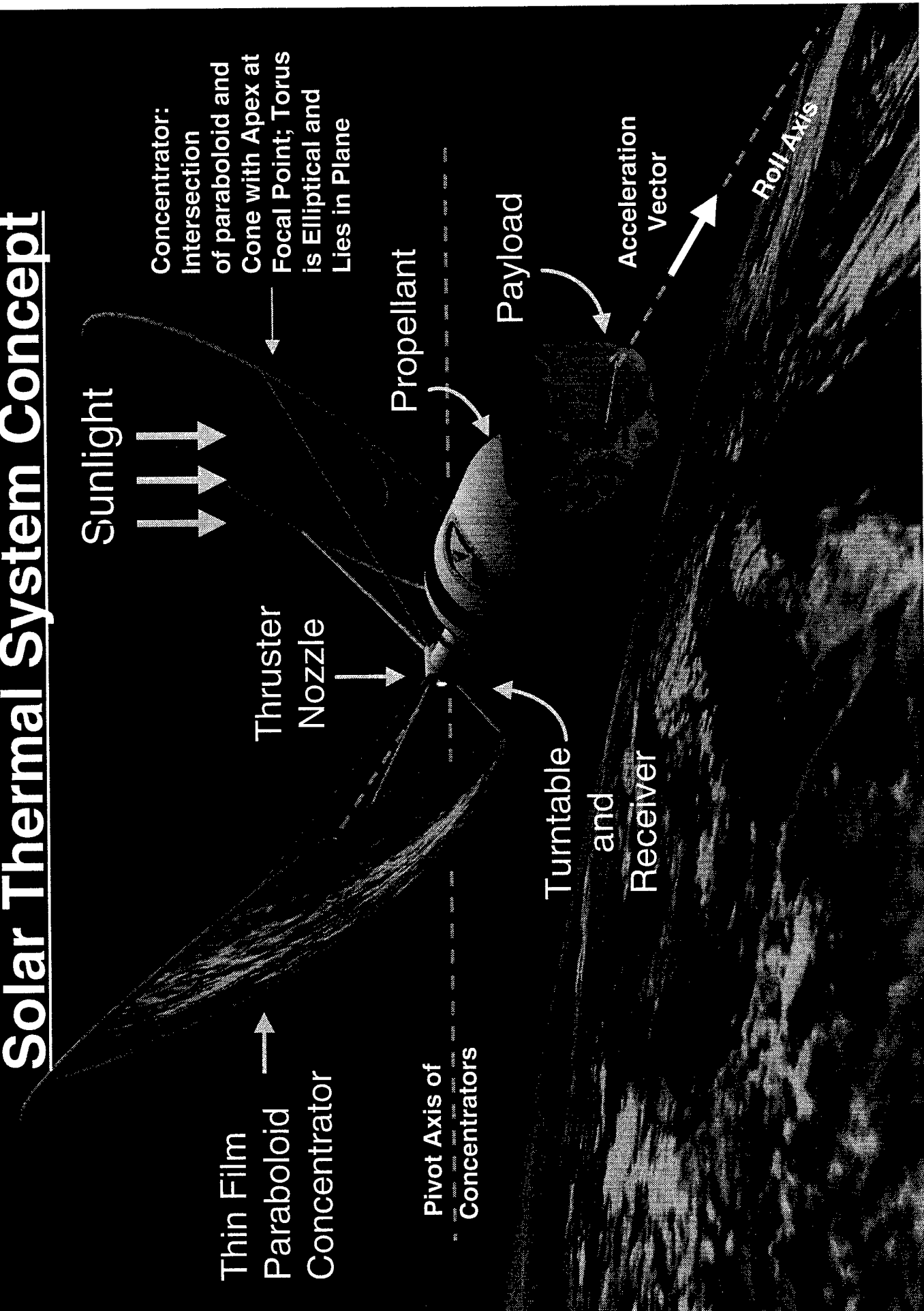
Propellant

Payload

Acceleration
Vector

Roll Axis

Turntable
and
Receiver



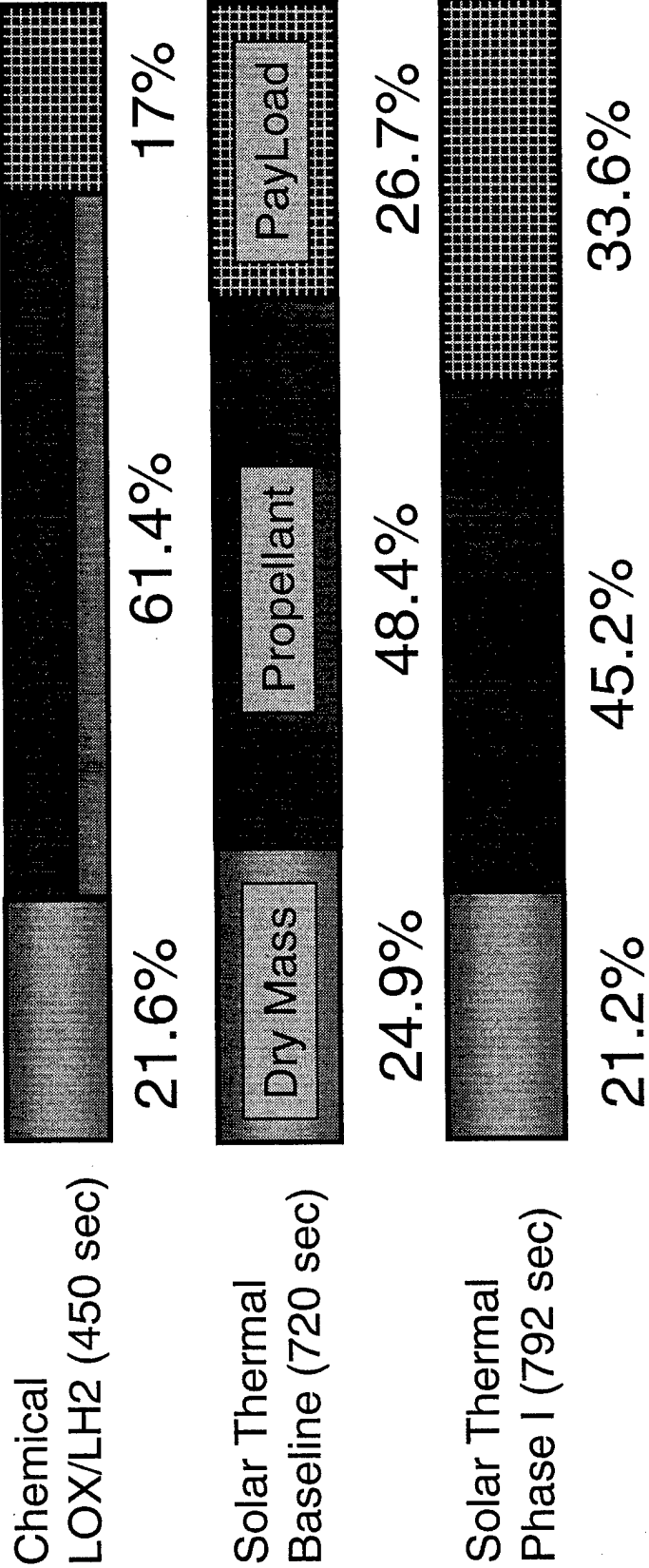


Propulsion Goals (IHPRPT Phase I)



IHPRPT Phase I Solar Propulsion Goal

- Increase Isp by 10% relative to Solar Thermal Baseline
- Decrease Dry Mass fraction by 15% relative to Solar Thermal Baseline
 - Baseline payload: 57% increase over chemical
 - Phase I payload: 26% increase over baseline



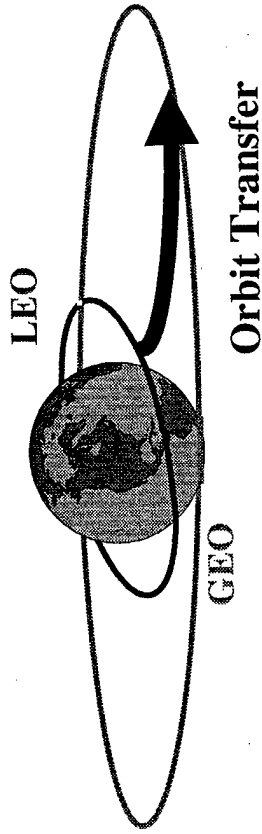


Solar Propulsion

IHRPT Phase I Payoffs



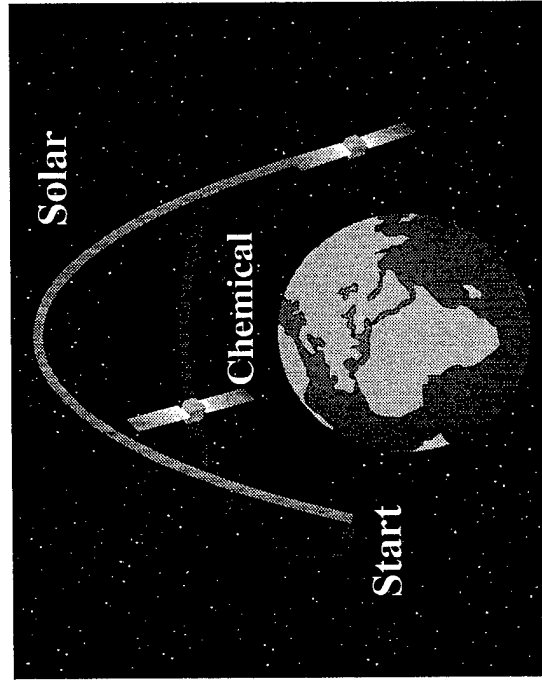
Orbit Transfer



+ 97 % Payload vs LOX-H2 upper stage (Atlas IIAS example below)

- \$40M Launch cost savings through reduced launch mass with step-down or dual manifesting (or)
- \$ 100M/year increase in revenue with added payload mass (transponders)
- 1 to 3 month mission duration

Orbit Repositioning



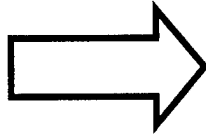
- 3X Faster move (or)
- 3X More moves versus storable chemical for same propellant mass



Funding Summary



	<u>1998</u>	<u>1999</u>	<u>2000</u>	<u>2001</u>
In - house Research	489	519	1161	2178
POM Dollars (\$K)				



Funding supports:

- In-house research and development: 2 researchers, 1 test engineer, 1 mechanic
- Test facility: 25 kW thermal input to test article
 - heliostat
 - concentrator
 - vacuum system
- Program management: IHPRPT Phase I demonstrator, DUS&T, SBIR



Principal Technology Program and Major Tasks



In - House Research Program Solar Thermal Component Evaluation

Program Objectives

- Quantify solar propulsion system payoffs: payload, mission duration, environmental radiation exposure
- Identify high payoff technology investment opportunities
- Validate achievement of Phase I IHPRPT ISP goal (792 sec)

Major Tasks

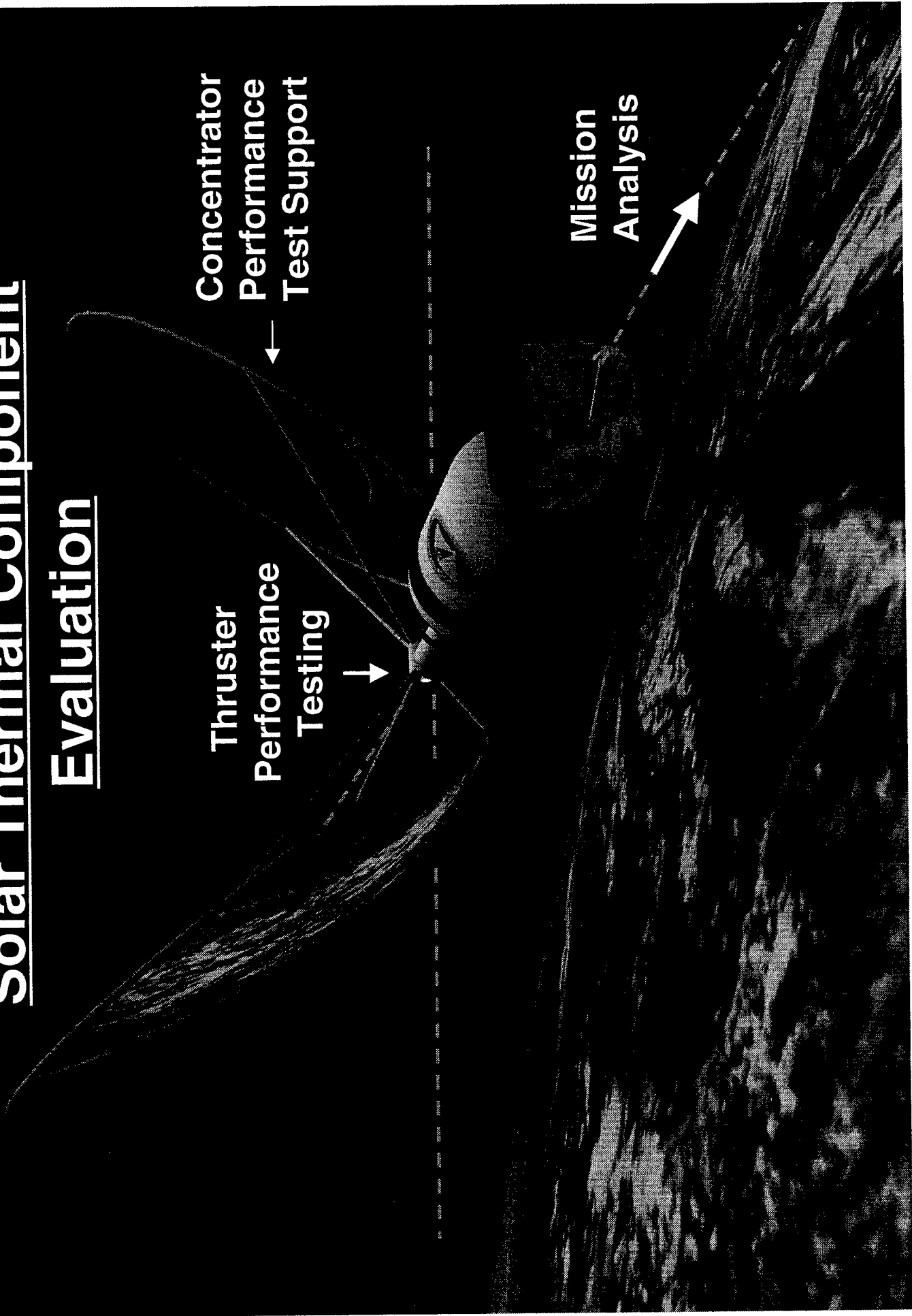
- Mission Analysis
- IHPRPT Solar Thruster Performance Testing
- IHPRPT Solar Concentrator Performance Test Support

Solar Thermal Component Evaluation

Concentrator
Performance
Test Support

Thruster
Performance
Testing

Mission
Analysis



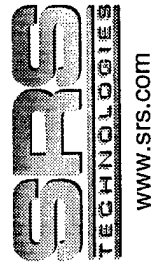
Major Tasks and Accomplishments



<u>Major Task</u>	<u>FY98</u>	<u>FY99</u>
Mission Analysis	Utilized existing models	Defined modeling priorities for Solar Thermal Propulsion 1) Update existing models 2) Solar Thermal / Solar Electric hybrid orbit transfer
Thruster Performance Testing	SRS Moly Thruster Test at AFRL SRS Coupon Sample Tests at AFRL	Defined pumping system requirements for accurate thrust measurements
Concentrator Performance Testing	Transmission measurement of inflatable concentrator at SRS Rigidization of inflatable concentrator at AFRL	Transmission and slope error measurement of inflatable concentrator at SRS Multiple deployments of inflatable concentrator at Thiokol Intensity and total power measurements at NASA MSFC

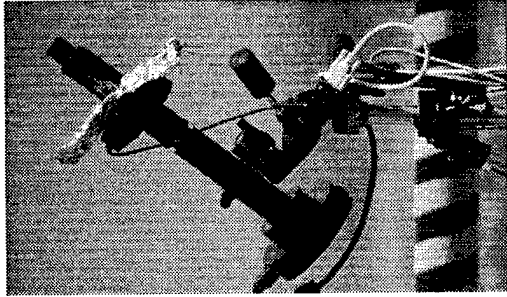


AFRL Characterization MSFC Solar Facility

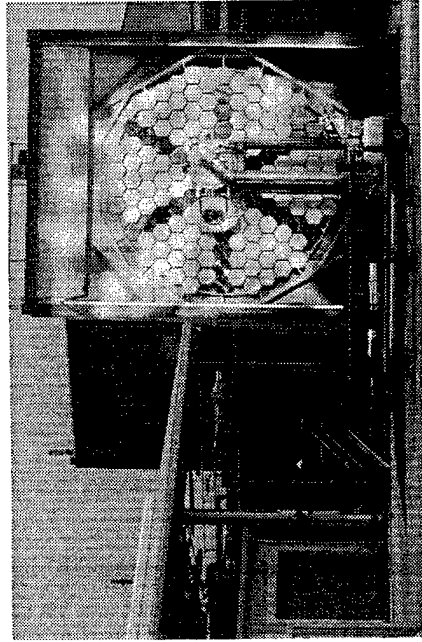


AFRL support for SRS report to NASA

- Dr. Mike Holmes of AFRL provided test support, data collection, and data analysis.
- Flux intensity data collection and analysis
- AFRL digital CCD camera and data collection and analysis tools.
 - Measurement of nominal solar flux for calibration
 - Helioostat performance measurement
 - Focal plane flux measurement



AFRL CCD
Camera



NASA MSFC
Solar Facility

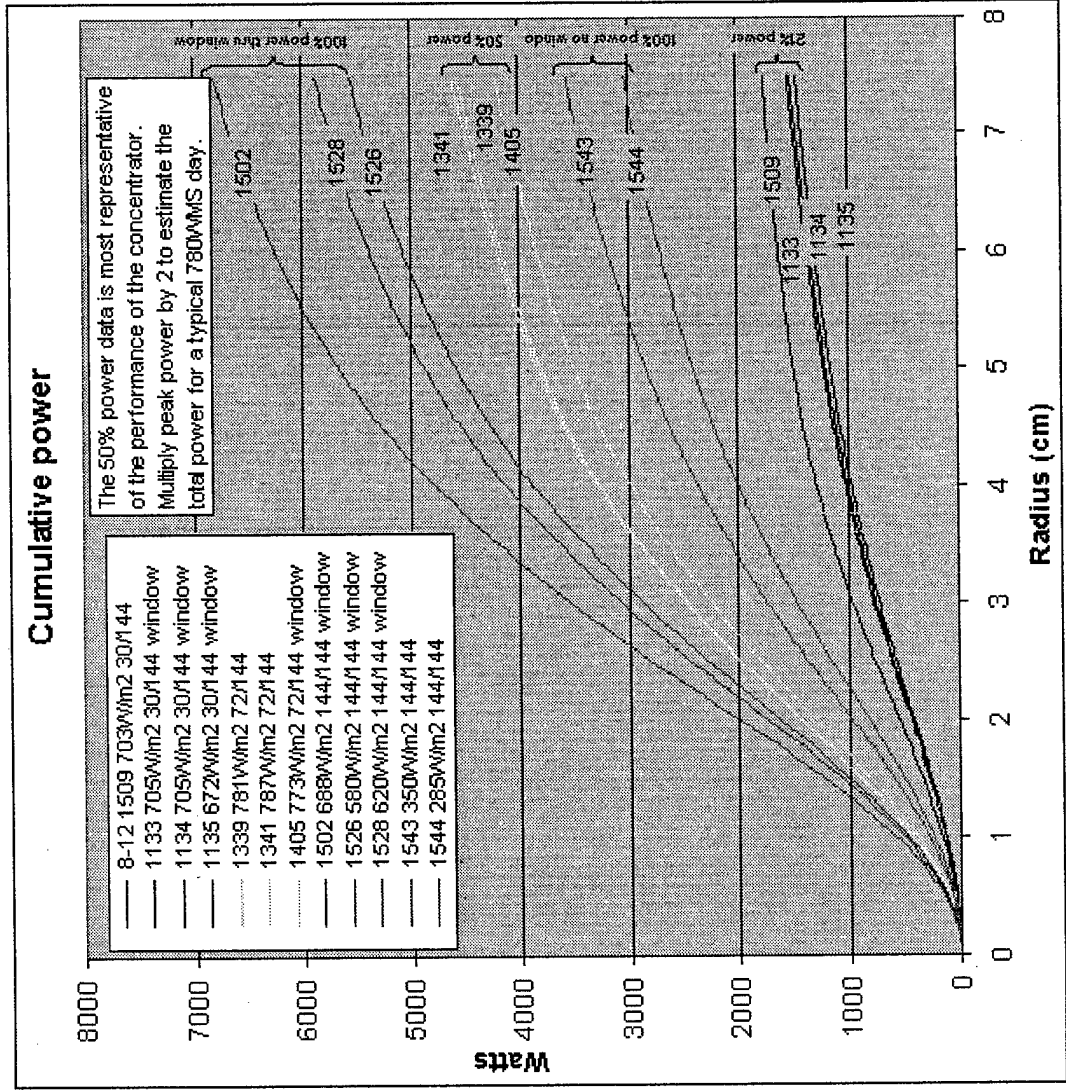


AFRL Characterization MSFC Solar Facility



AFRL Measurement and Analysis

- Methodology will be used for IHPRPT Demonstrator testing
- Characterized focal plane power as a function of radius
- Estimated peak power is ~ 9 kW
- Estimated peak flux intensity on the flux plate is ~290 W/cm²



Excerpt from SRS Report to NASA MSFC
MSFC Solar Thermal Facility:
Solar Power Checkout
PO# H31512D, 7/21/99 - 8/25/99,
Final Report



Major Tasks: FY00 and FY01

Mission Analysis



- 1) Enhance existing AFRL Solar Thermal Analysis Capability: Oct 99 - July 00
 - Augment existing models to support 7-180 day missions
 - currently limited to 14-60 days due to numerical method
 - Include power system integration, hydrogen propellant management, environmental radiation exposure
- 2) Examine Solar Thermal and Solar Electric hybrid propulsion for LEO-GEO orbit transfer missions: Oct 99 - Oct 00
 - Determine payload capability and environmental radiation exposure
- 3) Identify high payoff future technology investments: Aug 00 - Oct 01
 - Utilize mission analysis
 - Perform sensitivity analysis of payoffs versus technology improvements
 - Recommend IHRPT Phase II program objectives

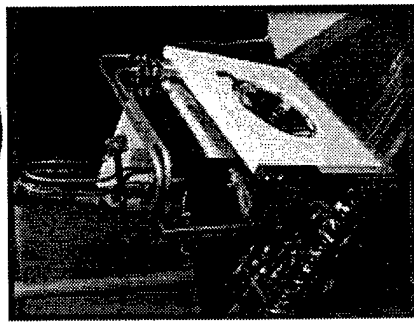


Major Tasks: FY00 and FY01

Thruster Performance Testing



- 1) Establish accurate thrust measurement capability in AFRL Solar Laboratory: Oct 99 - Mar 00
 - replace nitrogen injector (60 torr pressure) with 10K CFM blower
 - enable 1 torr test cell pressure with 1 g/s H₂ flow rate
 - support high accuracy (~1% uncertainty) thrust measurement
- 2) Validate achievement of Phase I IHPRPT ISP goal (792 sec): April 00 - Aug 00
 - Measure thrust and mass flow rate to infer specific impulse



- 3) Provide test support for commercial and military customers

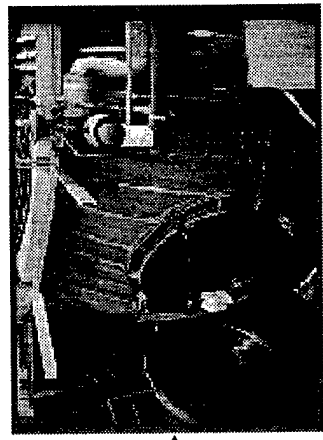


Solar Lab
25 kW
input

A-Cell
10 CFM
blower



SPEF
30' dia.
3 x 48" DP
2600 CFM
blower





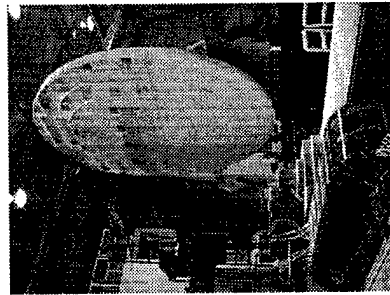
Major Tasks: FY00 and FY01

Concentrator Performance Test Support

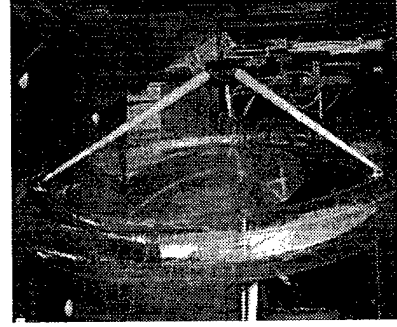


Characterize IHPRPT Phase I Concentrator (4 m x 6 m size)

- SRS Designed Concentrator, NASA MSFC machined mandrel
- Utilize proven AFRL developed modeling tools to predict intensity
 - Transmission, reflection, scattering, slope error, and polarization included
 - Previously used for 2m x 3m concentrator: ~ 5% uncertainty
- Perform flux measurements: AFRL NIST traceable equipment
- Concentrator shape measurement analysis to determine transmission and surface accuracy
 - Use AFRL models to evaluate contractor measurements
 - Use SRS Photogrametry data: 1 mm uncertainty
 - Use SRS Laser slope error measurements: 1 mrad uncert.
 - Use SRS Photo-ray trace data from a known distorted target
 - appropriate for 3-4 mrad accuracy



NASA MSFC
machining of
SRS designed
mandrel mockup



Concentrator
will be fabricated
using a metal
mandrel

AFRL supports
evaluation



Summary & Conclusion



Summary

- Solar Thermal Propulsion enables a doubling of payload to GEO
- Upgraded AFRL Solar Facility will provide accurate thrust measurements
- AFRL In-house research effort provides testing and analysis needed to confirm IHPRT Demonstrator capability and identify high payoff topics for follow-on efforts

Conclusion

The AFRL in-house research program is focused on making the deployment of Solar Thermal Propulsion a reality

